

Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) **EP 1 049 222 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.11.2000 Bulletin 2000/44

(51) Int Cl.7: **H01T 21/02**

(21) Application number: **00303605.0**

(22) Date of filing: **28.04.2000**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE**
Designated Extension States:
AL LT LV MK RO SI

(72) Inventor: **Matsutani, Wataru**
Mizuho-ku, Nagoya-shi, Aichi (JP)

(74) Representative: **Nicholls, Michael John**
J.A. KEMP & CO.
14, South Square
Gray's Inn
London WC1R 5LX (GB)

(30) Priority: **30.04.1999 JP 12413199**
20.05.1999 JP 14075199

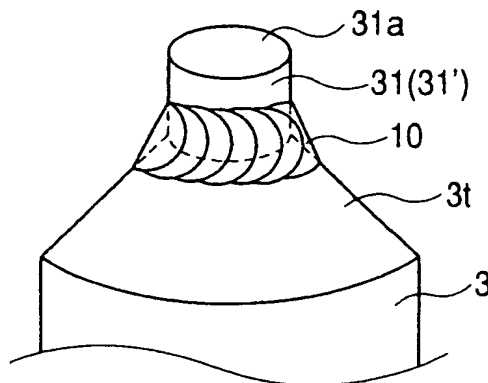
(71) Applicant: **NGK SPARK PLUG CO., LTD**
Mizuho-ku Nagoya-shi Aichi (JP)

(54) **Method of manufacturing spark plug and spark plug**

(57) A noble metal chip 31' is superimposed on a surface of a central electrode 3 made of a heat resisting alloy, the main component of which is Ni or Fe, to which the chip is secured so that a superimposed assembly 70 is constituted. A perimeter laser weld portion 10 across the noble metal chip 31' and a chip securing surface forming portion is formed around the outer surface of the chip of the superimposed assembly 70. Thus, the noble metal chip 31' is secured to the chip securing surface so that a noble-metal igniting portion 31 is consti-

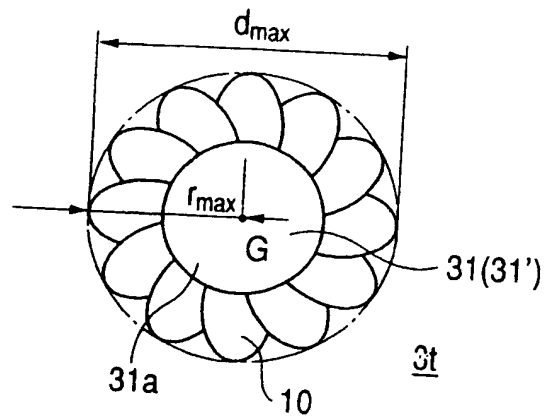
tuted. To form the perimeter laser weld portion 10 which has a maximum outer dimension dmax which is smaller than 2.0 mm and which does not reach the discharging surface 31a in a direction of the thickness of the noble metal chip 31', a laser beam source 50 is, as a light source of laser beams for use in a welding operation, employed which is arranged such that energy per pulse is 2 J to 6J, the length of the pulse is 1 millisecond to 10 milliseconds and the pulse generating frequency is 2 pulse/second to 20 pulse/second.

FIG. 2A



EP 1 049 222 A1

FIG. 2B



Description

[0001] The present invention relates to a method of manufacturing a spark plug and the spark plug.

[0002] As spark plugs serving as igniting means for internal combustion engines, spark plugs of a type having a noble-metal igniting portion have been used in recent years to improve resistance against sparks, the spark plugs being formed at the leading end of an electrode by welding a noble metal chip, the main component of which is Pt or Ir. When a noble metal chip is joined to the leading end surface of, for example, a central electrode, a method has been disclosed for example, in JP-A-6-45050 (U.S. Patent No. 5,320,569, EP-O 583 103 B1) and JP-A-10-112374. The method has the steps of superimposing a disc-shaped metal chip on the leading end of the central electrode and irradiating the outer surface of the superimposed surfaces with a laser beam while the central electrode is being rotated so that a perimeter laser weld portion is formed.

[0003] In recent years, the temperature in the combustion chamber has been raised because the performance of the internal combustion engine has been improved. Moreover, engines of a type having a structure that the diameter of the igniting portion of the spark plug is reduced to be 2.0 mm or smaller so that the igniting portion is allowed to project into the combustion chamber in order to improve ease of ignition have been widely employed. To improve resistance of the noble metal chip against separation in the severe atmosphere of use, a method has been employed with which a noble metal chip, the main component of which is Ir or Pt, is welded to an electrode made of a heat resisting alloy composed of Ni group or Fe group elements so as to form a noble-metal igniting portion.

[0004] The noble metal chip is usually welded to the spark plug by using pulse laser beams, such as YAG laser beams. The conditions under which the laser beam is applied have been determined such that the pulse generating frequency is a relatively low value of 0.5 pulse/second or lower. The foregoing method, however, requires an excessively long time of about 15 seconds to weld a noble metal chip having a diameter of about 0.7 mm. Therefore, there arises a problem of unsatisfactory productivity for each laser welding apparatus.

[0005] To solve the problem of deterioration in the productivity, it is effective to raise the pulse generating frequency of the laser beams. As a result of investigations performed by the inventor of the present invention, the following problem has been found. When the pulse generating frequency of the laser beam is simply raised to improve the productivity, the heat resisting alloy composed of Ni groups or Fe groups for use as the material of the electrode and having a low heat conductivity suffers from an unsatisfactory fall in the temperature. When the leading end of the electrode has a small diameter, the fall in the temperature of the electrode is sometimes delayed as compared with application of heat which is performed for each pulse of the laser beam. As a result, the rear portions of a weld portion 10 in the circumferential direction are heated excessively, as shown in Figs. 13A and 13B. Therefore, there arises a problem in that the weld portion is made to be nonuniform such that a rear weld portion 10s is deeply welded as compared with a front weld portion 10p. As an alternative to this, the width l of the weld portion is enlarged excessively. Since the weld portion 10 is constituted by an alloy of a material of a noble metal chip and a material of the electrode, the resistance against sparks of the weld portion 10 is inferior to that of only the noble metal chip. If the depth or the width of the weld portion 10 is enlarged excessively, the durability of an igniting portion 31 formed by welding the noble metal chip excessively deteriorates. In a region in which the width l of the weld portion 10 has been enlarged, the weld portion 10 is exposed to a discharging surface 31a in extreme cases. If the exposure is prevented, exposure of the weld portion 10 occurs in a case where the igniting portion 31 is somewhat consumed. In general, a spark plug is provided with the noble-metal igniting portion for the purpose of elongating the lifetime of the igniting portion (for example, lifetime corresponding to driving for 100,000 km to 160,000 km). If the foregoing problem arises, consumption of the exposed portion proceed. As a result, there sometimes arises a problem of misfire or the like because the spark discharge gap is enlarged in a relatively short time.

[0006] An object of the present invention is to provide a method of manufacturing a spark plug capable of significantly improving efficiency of a process for welding a noble metal chip to an electrode and obtaining a uniform weld portion and a spark plug having durability of an igniting portion to a degree not heretofore attained.

[0007] To solve the problems, according to the present invention, there is provided a method of manufacturing a spark plug comprising a central electrode and a ground electrode disposed such that the side surface of the ground electrode is opposite to the leading end surface of the central electrode and having a structure that a noble-metal igniting portion having a discharge surface is provided for at least either of the central electrode or the ground electrode at a position corresponding to a spark discharge gap by welding a noble metal chip, the method of manufacturing a spark plug comprising the steps of:

constituting at least a chip securing surface forming portion of the central electrode and/or the ground electrode is formed with a heat resisting alloy having Ni or Fe as a main component thereof and superimposing the noble metal chip on a chip securing surface so as to form a superimposed assembly;
providing a perimeter laser weld portion across the noble metal chip and the chip securing surface forming portion for the outer surface of the chip constituting the superimposed assembly so that the noble metal chip is secured

to the chip securing surface; and forming the perimeter laser weld portion having a maximum outer dimension d_{\max} plane-viewed from the chip interposing direction is smaller than 2.0 mm and so formed not to reach the discharge surface in a direction of the thickness of the noble metal chip by using, as a light source for laser welding, a pulse laser beam source having energy per pulse of 1.5 J to 6 J, a pulse length of 1 millisecond to 10 millisecond and a pulse generation frequency is 2 pulse/second to 20 pulse/second.

[0008] The chip securing surface forming portion is constituted by the heat resisting alloy, the main component of which is Fe or Ni, and the small-diameter perimeter laser weld portion having a maximum outer dimension d_{\max} which is smaller than 2.0 mm is formed. The inventors of the present invention has energetically performed studies. Thus, the following facts have been detected. That is, it is important that the pulse generating frequency satisfies a specific range to efficiently form a uniform weld portion. Moreover, it is important that conditions of the energy per pulse of a laser beam and the length of each pulse are made to be specific values. The following fact has been detected: in a state where the foregoing conditions are set, the problem of the nonuniform weld portion and the like can be solved if a frequency higher than the frequency employed in the conventional method is employed in only a specific pulse frequency range. Thus, the present invention has been established. That is, the laser beam having energy per pulse of 1.5 J to 6 J, a pulse length of 1 millisecond to 10 milliseconds is employed. Moreover, 2 pulse/second to 20 pulse/second which is a pulse generating frequency which is considerably higher than the pulse generating frequency employed in the conventional method is employed. Thus, a perimeter laser weld portion exhibiting excellent uniformity can significantly efficiently be formed.

[0009] In this specification, the maximum outer dimension d_{\max} of the perimeter laser weld portion is, as shown in Fig. 2B, defined as $d_{\max} = 2r_{\max}$ when the position of the geometric center of gravity of the discharging surface (31a) realized when the perimeter laser weld portion is projected onto a plane which is perpendicular to the central axis of the central electrode (3) is G and the distance from G to a farthest end of the perimeter laser weld portion is r_{\max} .

[0010] When the length of the pulse is shorter than 1 millisecond or when the energy of each pulse is smaller than 1.5 J, the quantity of heat which is input per pulse is reduced and, therefore, the weld portion cannot satisfactorily be formed. When the energy of each pulse is smaller than 1.5 J and also the length of the pulse is shorter than 1 millisecond, the quantity of heat input is reduced excessively. When the electrode is constituted by the heat resisting alloy composed of the Ni groups or the Fe groups, the influence of fall of the temperature of the electrode causes a fact that the electrode is not substantially fused. In the foregoing case, the weld portion cannot easily be formed.

[0011] When energy of each pulse is larger than 6 J or when the length of the pulse is longer than 10 milliseconds, accumulation of input heat caused from the laser beams easily occurs because the fall of the temperature of the electrode constituted by the heat resisting alloy composed of the Ni groups or the Fe groups is very small. Thus, there is apprehension that nonuniformity of the depth or the width of the weld portion occurs or the electrode is melted and deformed. When the energy of each pulse is larger than 6 J and the length of the pulse is longer than 10 milliseconds, molten metal is easily evaporated and scattered. In the foregoing case, there is apprehension that defects of the electrode, such as dents and holes, easily occur.

[0012] When the pulse generating frequency is lower than 2 pulse/second, the weld portion cannot efficiently be formed. When the pulse generating frequency is higher than 20 pulse/second, accumulation of heat inputs caused from the laser beam easily occurs. In the foregoing case, similar problems arise. It is preferable that the energy of each pulse is 2 J to 5 J. It is preferable that the length of the pulse is 1.5 millisecond to 6 milliseconds. It is preferable that the pulse generating frequency is 2 pulse/second to 12 pulse/second. In this specification, energy of each pulse is a value obtained from a process in which a laser beam emitted from the laser beam source is received by an energy detection apparatus, such as a calorimeter or a power meter, before the laser welding operation is performed. Thus, energy per unit time (for example, one second) is measured, and then the energy is divided by the number of pulses per second.

[0013] When the foregoing method is employed, the perimeter laser weld portion having the maximum outer dimension d_{\max} which is smaller than 2.0 mm is formed by using the heat resisting alloy composed of Fe groups or Ni groups as follows: A heretofore difficult laser weld portion can be formed. Specifically, a laser weld portion can be formed which has a structure that a ratio l_{\min}/l_{\max} of a minimum width l_{\min} and a maximum width l_{\max} of the perimeter laser weld portion in the superimposing direction of the noble metal chip is 0.7 or higher.

[0014] A spark plug according to the present invention comprises: a central electrode; a ground electrode disposed such that the side surface of the ground electrode is opposite to the leading end surface of the central electrode; and a noble-metal igniting portion having a discharge surface and provided for at least either of the central electrode or the ground electrode at a position corresponding to a spark discharge gap by welding a noble metal chip. In the spark plug, a chip securing surface forming portion of the central electrode and/or the ground electrode is constituted by a heat resisting alloy having Ni or Fe as a main component thereof. A perimeter laser weld portion is formed on the outer surface of the chip across the noble metal chip and the chip securing surface forming portion. A maximum outer di-

mension d_{max} of the perimeter laser weld portion plane-viewed from the chip interposing direction is smaller than 2.0mm. The perimeter laser weld portion does not reach the discharge surface in the thickness direction of the noble metal chip. A ratio l_{min}/l_{max} of the perimeter laser weld portion in the superimposed direction to the chip securing surface is 0.7 or higher.

[0015] The fact that l_{min}/l_{max} can be made to be 0.7 or higher means a fact that circumferential dispersion of the distance from the discharging surface of the noble-metal igniting portion to the end of the perimeter laser weld portion adjacent to the discharging surface can satisfactorily be prevented. As a result, a problem can effectively be prevented which arises in that the discharging surface of the weld portion is exposed to the outside at a position at which the width of the laser weld portion is enlarged and the durability of the spark plug deteriorates. The manufacturing method according to the present invention is able to make the ratio l_{min}/l_{max} to be 0.9 or higher which is furthermore preferred value by appropriately determining the welding conditions.

[0016] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 is a vertical cross sectional view showing an embodiment of a spark plug according to the present invention and an enlarged view showing an essential portion of the same;

Fig. 2A is an enlarged perspective view of a leading end of a central electrode of the spark plug shown in Fig. 1 and Fig. 2B is a plan view showing the front surface of the central electrode;

Fig. 3A is a vertical cross sectional view of Fig. 2A and Fig. 3B is a vertical cross sectional view of its modification; Figs. 4A to 4D are developed views of a perimeter laser weld portion;

Figs. 5A to 5D are diagrams showing a process for manufacturing an igniting portion of the central electrode of the spark plug shown in Fig. 1;

Figs. 6A and 6B are diagrams showing a modification of the manufacturing process shown in Figs. 5A to 5D;

Fig. 7 is a diagram showing another modification of the same;

Figs. 8A and 8B are diagrams showing another modification of the same;

Fig. 9 is a diagram showing a process for manufacturing a spark plug according to the modification;

Fig. 10A is a perspective view showing an essential portion of the spark plug manufactured by the manufacturing process shown in Fig. 9, Figs. 10B and 10C are vertical cross sectional view showing the spark plug, and Figs. 10A' to 10C' are vertical cross sectional view showing a modification of the spark plug as shown in Figs. 10A to 10C, respectively.;

Fig. 11 is a perspective view showing an igniting portion of the ground electrode;

Figs. 12A and 12B are diagrams showing a process for manufacturing the spark plug of Fig. 11.; and

Figs. 13A and 13B are diagrams showing problems experienced with the conventional manufacturing method.

[0017] A spark plug 100 according to the embodiment of the present invention and shown in Fig. 1 incorporates a cylindrical main metal shell 1 and an insulating member 2 fitted to the inside portion of the main metal shell 1 such that a leading end 21 of the insulating member 2 projects. Moreover, the spark plug 100 incorporates a central electrode 3 disposed on the inside of the insulating member 2 in a state in which a noble-metal igniting portion (hereinafter simply called an "igniting portion") 31 projects. Moreover, the spark plug 100 incorporates a ground electrode 4 having an end joined to the main metal shell 1 by welding or the like and another end bent sideways and disposed such that the side surface of the ground electrode 4 is positioned opposite to the leading end of the central electrode 3. The ground electrode 4 is provided with a noble-metal igniting portion (hereinafter simply called an "igniting portion") 32 disposed opposite to the igniting portion 31. A gap between the opposite igniting portion 31 and igniting portion 32 is a spark discharge gap g .

[0018] In this specification, the "igniting portion" is a portion of the joined noble metal chip on which an influence of change in the composition occurring due to the welding operation is not exerted (for example, a residual portion except for a portion alloyed with the material of the ground electrode and the material of the central electrode owing to the welding operation).

[0019] The insulating member 2 is made of a sintered body of ceramic, such as alumina or aluminum nitride. The insulating member 2 has a hole portion 6 formed in the axial direction of the insulating member 2 to receive the central electrode 3. The main metal shell 1 is formed into a cylindrical shape and made of a metal material, such as low-carbon steel, to constitute a housing of the spark plug 100. Moreover, a screw portion 7 for joining the spark plug 100 to an engine block (not shown) is formed on the outer surface of the main metal shell 1.

[0020] A structure may be employed in which either of the igniting portion 31 or the opposite igniting portion 32 is omitted. In the foregoing case, spark discharge gap g is formed between the igniting portion 31 and the side surface of the ground electrode 4 for which the igniting portion is not provided. As an alternative to this, the spark discharge gap g is formed between the opposite igniting portion 32 and the front surface of the central electrode 3 for which the igniting portion is not provided.

[0021] Each of the central electrode 3 and the ground electrode 4 has the chip securing surface forming portion which has a structure that at least the surface layer is made of a heat resisting alloy, the main component of which is Ni or Fe (the "main component" means a component contained at a highest content, that is, "a component contained at 50 wt% or higher" is not meant). The heat resisting alloy, the main component of which is Ni or Fe, may be any one of the following materials.

(1) Heat Resisting Alloy Containing Ni Group: which is, in this specification, a generic name of heat resisting alloys of a type containing Ni by 40 wt% to 85 % and a balance mainly consisting of one or more types of the following materials: Cr, Co, Mo, W, Nb, Al, Ti and Fe. Specifically, the following materials may be employed (their trade names are shown. Note that the composition of each of the following alloys is disclosed in a document (Metal Data Handbook Edition No. 3 (Maruzen), pp. 138) is omitted from description.

ASTROLOY, CABOT 214, D-979, HASTELLOY C22', HASTELLOY C276, HASTELLOY G30, HASTELLOY S, HASTELLOY X, HAYNESS 230, INCONEL 587, INCONEL 597, INCONEL 600, INCONEL 601, INCONEL 617, INCONEL 625, INCONEL 706, INCONEL 718, INCONEL X750, KSN, M-252, NIMONIC 75, NIMONIC 80A, NIMONIC 90, NIMONIC 105, NIMONIC 115, NIMONIC 263, NIMONIC 942, NIMONIC PE11, NIMONIC PE16, NIMONIC PK33, PYROMET 860, RENE 41, RENE 95, SSS 113MA, UDIMENT 400, UDIMENT 500, UDIMENT 520, UDIMENT 630, UDIMENT 700, UDIMENT 710, UDIMENT 720, UNITEP AF2-1 DA6 and WASPALOY.

(2) Heat Resisting Alloy Containing Fe Group: which is, in this specification, a generic name of heat resisting alloys of a type containing Fe by 20 wt% to 60 wt% and a balance mainly consisting of one or more types of the following materials: Cr, Co, Mo, W, Nb, Al, Ti and Ni. Specifically, the following materials may be employed (their trade names are shown. Note that the composition of each of the following alloys is disclosed in a document (Metal Data Handbook Edition No. 3 (Maruzen), pp. 138) is omitted from description.

A-286, ALLOY 901, DISCALOY, HAYNES 556, INCOLOY 800, INCOLOY 801, INCOLOY 802, INCOLOY 807, INCOLOY 825, INCOLOY 903, INCOLOY 907, INCOLOY 909, N-155, PYROMET CTX-1, PYROMET CTX-3, S-590, V-57, PYROMET CTX-1, 16-25-6, 17-14CuMo, 19-9DL and 20-Cb3.

[0022] On the other hand, each of the igniting portion 31 and the opposite igniting portion 32 is mainly constituted by noble metal, the main component of which is Ir or Pt. When the foregoing noble metal is employed, the consumption resistance of the igniting portion can be improved even in an environmental in which the temperature of the central electrode is easily raised. Moreover, weldability with respect to the foregoing heat resisting alloy can be improved. When noble metal, the base material of which is Pt, is employed, Pt may be employed solely. As an alternative to this, a Pt-Ni alloy (for example, a Ni alloy containing Pt by, for example, 1 wt% to 30 wt%), a Pt-Ir alloy or a Pt-Ir-Ni alloy may be employed. The alloy, the main component of which is Ir, may be an Ir-Pt alloy or an Ir-Rh alloy.

[0023] When the Ir-type noble metal is employed, oxide (including composite oxide) of a metal element belonging to group 3A (so-called "rare earth metal") of the periodic table or group 4A (Ti, Zr or Hf) may be contained in a range from 0.1 wt% to 15 wt%. Thus, oxidation and volatilization of the Ir component can effectively be prevented. Hence it follows that resistance of the igniting portion can be improved. It is preferable that Y_2O_3 is employed as the oxide. As an alternative to this, La_2O_3 , ThO_2 or ZrO_2 may be employed. In the foregoing case, the metal component may be Ir in the form of a sole body as well as the Ir alloy.

[0024] The central electrode 3 has a tapered surface 3t having a truncated cone shape and formed at the leading end of the central electrode 3 so that the diameter of the central electrode 3 is reduced. Moreover, a disc-shape noble metal chip 31' (see Figs. 5A to 5d) constituting the igniting portion 31 and having the composition of an alloy is superimposed on a front surface 3s of the central electrode 3. In addition, a perimeter laser weld portion 10 (hereinafter simply called a "weld portion") is, by laser welding, formed along the ends of the joined surface so as to be secured. Thus, the igniting portion 31 is formed. The opposite igniting portion 32 is formed by performing registration of the position of the noble metal chip 32' (see Figs. 12A and 12B) and that of the ground electrode 4 at the position corresponding to the igniting portion 31. Similarly, a weld portion 20 is formed along the ends of the joined surfaces so as to be secured. The foregoing chips can be obtained by forming a molten alloy prepared by mixing and dissolving alloy components such that a predetermined composition is realized into a plate-like shape by hot rolling. Then, the plate-like member is punched so as to be formed into a predetermined chip shape by a hot punching process. As an alternative to this, a method may be employed with which an alloy is formed into a linear or a rod material by hot rolling or hot forging so as to be cut in the lengthwise direction to have a predetermined length. As an alternative to this, a spherical member may be employed which has been molded by an atomizing method. Each of the chips 31' and 32' has a diameter d_c of 0.4 mm to 1.2 mm and a thickness t_c of 0.5 mm to 1.5 mm.

[0025] Since the igniting portions 31 and 32 are formed by substantially the same welding methods, a method of forming the igniting portion 31 adjacent to the central electrode 3 will now be described. As shown in Fig. 5A, a front surface 3s of the central electrode 3 is used as a chip securing surface (the surface to which the chip is secured). Then, the noble metal chip 31' is superimposed on the front surface 3s so that a superimposed assembly 70 is con-

stituted. Then, the perimeter laser weld portion 10 is formed along the outer surface of the noble metal chip 31' of the superimposed assembly 70 at a position across the noble metal chip 31' and the chip securing surface. As a source of the laser beam, a pulse laser beam source (for example, a YAG laser beam source) 50 is employed which is arranged such that energy per pulse is 1.5 J to 6 J, the length of the pulse is 1 millisecond to 10 milliseconds and the pulse generating frequency is 2 pulse/second to 20 pulse/second. The perimeter laser weld portion 10 constituted by using the chip 31' having the above-mentioned size under the foregoing conditions has a maximum outer dimension d_{\max} which is smaller than 2.0 mm, plane-viewed from the chip interposing direction as shown in Fig. 2B. Moreover, the perimeter laser weld portion 10 does not reach a discharging surface 31a in a direction of the thickness of the noble metal chip 31'. It is preferable that the maximum outer dimension d_{\max} is 0.4 mm or larger. When the d_{\max} is smaller than 0.4 mm, a uniform weld portion cannot easily be formed if the diameter of the laser beam is considerably reduced. Therefore, normal formation of the igniting portion is sometimes inhibited.

[0026] Each of the heat resisting alloy for use as the material of the electrode having a low heat conductivity at 800°C which is 30 W/m·K or lower has a characteristic that heat is easily accumulated in the alloy during the laser welding operation. The laser beam is employed which is arranged such that energy per pulse is 1.5 J to 6 J and the length of the pulse is 1 millisecond to 10 milliseconds. Thus, satisfactory uniformity of the perimeter laser weld portion 10 can be realized if the pulse generating frequency of 2 pulse/second to 20 pulse/second is employed. Specifically, a ratio l_{\min}/l_{\max} of minimum width l_{\min} and maximum width l_{\max} of the perimeter laser weld portion 10 in a direction of central axis O of the chip 31' or the central electrode 3 can be made to be 0.7 or higher (preferably 0.9 or higher).

[0027] Fig. 4A is a developed view of a projected image formed when the perimeter laser weld portion 10 has been projected onto a cylindrical surface (having a diameter which is the same as the outer diameter of the discharging surface 31a) which is coaxial to the central axis O. In Fig. 4A, l_{\min} and l_{\max} are shown. Shortest distance h_{\min} from outer end TL of the discharging surface 31a to an end of the perimeter laser weld portion 10 adjacent to the discharging surface 31a will now be described. Assuming that the distance from each end of the perimeter laser weld portion 10 adjacent to the discharging surface 31a to integral central line UC_m is average thickness hav of the igniting portions, it is preferable that h_{\min}/hav is 0.7 or higher similarly to l_{\min}/l_{\max} . Thus, a problem can effectively be prevented which arises in that the weld portion is exposed to the discharging surface at the position at which h_{\min} is realized (in many cases, a position at which the perimeter laser weld portion 10 has largest width (l_{\max})) owing to slight consumption of the noble-metal igniting portion and, therefore, misfire or the like occurs.

[0028] When the two side portions of the perimeter laser weld portion 10 across the central axis O of the perimeter laser weld portion 10 are not connected to each other in the radial direction as shown in Fig. 3A (in the foregoing case, the perimeter laser weld portion 10 is formed into an annular shape), thickness t_c of the chip can be measured from the axial cross section after the welding operation has been completed. When the two sides portions of the weld portion 10 are connected to each other in the radial direction as shown in Fig. 3B (in the foregoing case, the perimeter laser weld portion 10 is formed into a disc shape), reference line CM is set at an intermediate position between integral central lines UC_m and LC_m on the two side ends of the perimeter laser weld portion 10 in the widthwise direction, as shown in Fig. 4A. Moreover, an assumption is made that distance H from the reference line CM to the outer end TL of the discharging surface 31a is t_c to estimate the thickness.

[0029] The diameter d_c of the chip is arbitrarily determined to satisfy a range from 0.4 mm to 1.2 mm to correspond to the durability and the igniting performance required of the spark plug. In general, the noble metal chip is a costly chip. Therefore, the quantity of use of the noble metal chip must be reduced by reducing the thickness t_c of the noble metal chip to 0.5 mm to 1.5 mm. It is preferable that the average thickness hav of the igniting portion is 0.2 mm to 1.0 mm. The reason for this lies in that a structure that hav is smaller than 0.2 mm causes exposure of the weld portion to the discharging surface owing to slight consumption of the noble-metal igniting portion to occur. Thus, the durability of the spark plug sometimes deteriorates. If hav is larger than 1.0 mm, the spark plug, which is at the end of its life owing to enlargement of the gap, must be changed in a state in which a considerably large quantity of the noble metal chip remains. Therefore, when the thickness t_c of the chip can be confirmed even after the welding operation has been completed, it is preferable that ratio hav/t_c of the average thickness hav of the igniting portion and the thickness t_c of the chip is about 0.13 to 2.0. When the end of the noble metal chip 31' opposite to the discharging surface projects adjacent to the base portion as compared with the weld portion 10 as shown in Fig. 4B, there arises a problem in that the overall projecting portion comes naught regardless of the end of the life even if hav/t_c is 0.2 to 1.0.

[0030] To prevent separation of the noble metal chip from the central electrode, it is preferable that lav is 0.4 mm or larger on an assumption that the distance between UC_m and LC_m is average width lav of the weld portion. When two sides portion of the weld portion across the central axis are not connected to each other in the radial direction as shown in Fig. 4C, it is preferable that $t_c - hav$ is 0.2 mm or larger. A case will now be described in which the two side portions of the weld portion in the radial direction are connected to each other as shown in Fig. 4D. An assumption is made that the distance from the discharging surface 31a to a position on the joint surface between the perimeter laser weld portion 10 and the igniting portion 31 at which the perimeter laser weld portion 10 has a smallest thickness in the axial direction of the central electrode 3 is t_{c2} and the distance to a position at which the perimeter laser weld portion 10 has a smallest

thickness on the joint surface between the perimeter laser weld portion 10 and the central electrode 3 is tc3. It is preferable that tc3 - tc2 is 0.2 mm or longer.

[0031] The preferred welding conditions according to the present invention will now be described.

[0032] When the noble metal chip 31' is formed into the disc-like shape according to this embodiment, it is rational to employ a method with which the outer surface of the igniting portion 31 is irradiated with laser beam LB while the superimposed assembly 70 of the igniting portion 31 and the central electrode 3 are being rotated around the central axis O of the igniting portion 31 with respect to a laser beam source 50, as shown in Fig. 5B. Thus, the perimeter laser weld portion can uniformly be formed. In the foregoing case, only either of the superimposed assembly 70 or the laser beam source 50 may be rotated. As an alternative to this, both of the units may be rotated (for example, in opposite directions).

[0033] In the foregoing case, it is preferable that the rotational speed is adjusted as follows: the relative rotational speed between the superimposed assembly 70 and the laser beam source 50 is 10 rpm or higher (preferably 12 rpm or higher) when only one laser beam source 50 is used. To perform the perimeter laser welding operation, the superimposed assembly 70 and the laser beam source 50 must relatively be rotated by one or more times. If the relative rotational speed is lower than 10 rpm, time for which the welding operation is performed in one rotation, that is, dead time for manufacturing one spark plug, is elongated excessively. Therefore, an advantage cannot always be realized as compared with the conventional method.

[0034] When a plurality of laser beam sources are disposed in the circumferential direction of the chip 31' at predetermined intervals as shown in Fig. 6B or Fig. 7 to perform the welding operation, the number of revolutions required until the welding operation is completed can sometimes be reduced. Thus, the lower limit of the relative rotational speed can sometimes be reduced. When two laser beam source 50a and 50b disposed apart from each other by an angular degree of about 180° are used to perform the welding operation as shown in Figs. 6A and 6B, the laser beam sources 50a and 50b are operated for corresponding weld portions 10a and 10b each of which corresponds to the halfway of the round. When three laser beam sources 50a to 50c disposed apart from one another at intervals of about 120° as shown in Fig. 7 are used to perform the welding operation, the laser beam sources 50a to 50c are required to be operated for weld portions 10a to 10c each of which corresponds to about 1/3 round.

[0035] Also in a case where a plurality of laser beam sources are employed, each laser beam source must satisfy the laser welding conditions according to the present invention. The reason for this will now be described. When a plurality of laser beam sources (n which satisfies the relationship that $n \geq 2$) are used, rise in the temperature of the chip 31' occurring when laser beams are applied simultaneously takes place considerably. As described above, each laser beam source is required to irradiate the weld portion corresponding to substantially (1/n) round of the chip 31'. Therefore, the welding operation can be completed in a time which is (1/n) of time required when a sole laser beam source is employed. As a result, time required to input heat to the chip 31' can be shortened and, therefore, a problem that the width of each weld portion is enlarged excessively can be prevented. When the plural laser beam sources are employed to simultaneously apply laser beams, time required to complete the weld portion can be shortened. Thus, productivity can be improved.

[0036] The upper limit of the relative rotational speed will now be described. When the superimposed assembly 70 is rotated, it is preferable that the highest rotational speed is not higher than about 240 rpm (four rotations per second) in order to prevent deformation and scatter of molten metal owing to centrifugal force and produced during the welding operation. On the other hand, centrifugal force which is exerted on the perimeter laser weld portion 10 is considered to be enlarged substantially in proportion to the maximum outer dimension dmax and enlarged substantially in proportion to the square of the rotational angular velocity. When the foregoing facts are considered, it is preferable that the rotational speed of the superimposed assembly 70 is set to be a value which is defined by the following equation (note that the unit of dmax below is mm):

$$V_{\max} = 5\pi (2/d_{\max})^{1/2} \text{ (unit: radian/second)} \quad (1)$$

[0037] As can be understood from equation (1), Vmax can be enlarged as dmax is reduced. When dmax = 2.0 mm, Vmax is about 150 rpm. When dmax = 1.5 mm, Vmax is 173 rpm. When dmax = 0.7 mm, Vmax = 253 rpm. When both of the superimposed assembly 70 and the laser beam source 50 are rotated to realize a predetermined relative rotational speed, raising of the rotational speed of the portion adjacent to the central electrode enables the rotational speed of the mechanism of the laser beam source 50 which must have a relatively complex structure to be reduced (or no rotation is required). Thus, simplification of the mechanism of the laser beam source 50 or reduction in the load of the rotation which must be born is permitted.

[0038] When the relationship that dmax < 0.78 mm is substantially held, Vmax is higher than 240 rpm which is the

preferred upper limit in accordance with equation (1). As a result of investigations performed by the inventor of the present invention, at least five pulse-welded beads must be formed in one round to form the weld portion 10 which is completely continued in the circumferential direction by using the laser beam having energy of 1.5 J to 6 J per pulse even in a case of the foregoing chip having the small diameter. The foregoing velocity of 240 rpm corresponds to four rotations per second which permits only five pulses per second or smaller if 20 pulse/second, which is the upper limit of the pulse generating frequency, is set. Therefore, if the rotational speed is higher than the above-mentioned speed, weld beads 10d are intermittently formed in the circumferential direction, as shown in Fig. 8A. Therefore, there is apprehension that pulse weld beads continued in the circumferential direction cannot be formed during one rotation. Therefore, it is advantageous that the rotational speed of about 240 rpm is maintained from a viewpoint of equation (1) if rotational speed higher than 240 rpm is permitted. When execution of second and following welding operations is permitted, shift of the angular phase at which the weld beads 10d are formed enables the weld portion 10 continued in the circumferential direction to be formed, as shown in Fig. 8B.

[0039] When the laser beam source 50 is rotated, it is preferable that the rotational speed of the laser beam source 50 is 90 rpm or lower in order to prevent undesirable shift of the position irradiated with the emitted laser beam.

[0040] To form the weld portion 10 which does not reach the discharging surface 31a when the thickness t_c of the noble metal chip 31' is small as described above, it is effective to apply the pulse laser beam LB from a diagonally upper position. Specifically, as shown in Figs. 5B and 5C, it is preferable that the superimposed assembly 70 is irradiated with the pulse laser beam LB as follows. That is, an end Q of intersection between the surface to which the chip is secured (which is the front surface of the central electrode 3) and the outer surface of the chip is included in a spot of the laser beam LB and irradiation angle θ with respect to the surface to which the chip is secured satisfies a range from 0° to 60° (for example, 45°).

[0041] To facilitate location and securing of the noble metal chip 31' with respect to the surface to which the chip is secured, a process may be employed in which the locating recess 3a corresponding to the outer shape of the chip is formed in the surface to which the chip is secured, as shown in Fig. 5D. Then, the noble metal chip 31' is fitted in the locating recess 3a to constitute the superimposed assembly 70. To reliably perform the welding and joining operation in the foregoing case, it is preferable that the end Q of the intersection between the end of the opening portion of the recess 3a and the outer surface of the chip is irradiated with the pulse laser beam LB.

[0042] Another method arranged as shown in Fig. 9 may be employed. That is, a cylindrical projection 3d is formed at the leading end of the tapered surface 3t of the central electrode 3. Moreover, the flat front surface 3s is used as the surface to which the chip is secured. The noble metal chip 31' is superimposed on the front surface 3s. Then, the pulse laser beam LB is applied to the end Q of the intersection between the surface to which the chip is secured and the outer surface of the chip. Fig. 10A is an enlarged perspective view showing a portion in the vicinity of the igniting portion 31 of a spark plug manufactured as described above. Figs. 10B and 10C are vertical cross sectional views of the foregoing portion. Fig. 10B shows a state in which the two side portions across the central axis O of the weld portion 10 are not connected to each other. Fig. 10C shows a state in which the two side portions are connected to each other in the radial direction. As shown in Figs. 10A', 10B' and 10C', a shape may be employed in which the overall body of the projection 3d is melted so as to be included in the weld portion 10.

[0043] Fig. 11 shows a state in which the igniting portion 32 of the ground electrode 4 is formed. A perimeter laser weld portion 20 similar to that of the central electrode 3 is formed. As shown in Fig. 12A, the side surface which will face the spark discharge gap g of the ground electrode 4 (see Fig. 1) is used as the surface to which the chip is secured. A recess 4a is formed in the foregoing surface. Then, the noble metal chip 32' is fitted and secured into the recess 4a. In the foregoing state, the laser beam source 50 is operated similarly to the method shown in Fig. 5B or the like so that the weld portion 20 is formed.

[0044] Table 1 shows preferred laser welding conditions (energy per pulse, the length of the pulse, the pulse generating frequency and the relative number of revolutions between the laser beam source and the superimposed assembly (note that the number of the laser beam source is one) when the weld portions having a variety of d_{max} are formed by using noble metal chips made of a variety of materials.

Table 1

| d_{max} (mm) | Composition of Noble Metal chip (wt%) | Energy of Laser Beam (J/pulse) | Length of Pulse (μ s) | Pulse Generating Frequency (pulse/second) | Relative Number of Revolutions (rpm) |
|----------------|---------------------------------------|--------------------------------|----------------------------|-------------------------------------------|--------------------------------------|
| 1.1 | 90Pt-10Ir, 80Pt-20Ir | 2 | 2 | 12 | 60 |

Table 1 (continued)

| dmax (mm) | Composition of Noble Metal chip (wt%) | Energy of Laser Beam (J/pulse) | Length of Pulse (μ s) | Pulse Generating Frequency (pulse/second) | Relative Number of Revolutions (rpm) |
|-----------|--------------------------------------------------------------------|--------------------------------|----------------------------|-------------------------------------------|--------------------------------------|
| 0.5 | 100Ir, 95Ir-5Rh, 95Ir-5Pt 90Ir-10Rh, 80Ir-20Rh | 2 | 2 | 9 | 60 |
| 1.9 | 95Ir-5Pt, 80Ir-20Rh 90Ir-10Rh, 98Ir-2Y ₂ O ₃ | 3 | 6 | 3 | 10 |

Examples

[0045] To confirm the effects of the present invention, the following experiments were performed. First, INCONEL 600 was employed to manufacture the central electrode 3 formed as shown in Fig. 1. Note that outer diameter D1 of the base portion shown in Fig. 5A was 2.5 mm, diameter D2 of the front surface was 1.3 mm and the tapered angle of the tapered surface 3t was 45°. On the other hand, noble metal chips having a variety of diameters such that the thickness was 0.6 mm to 0.8 mm and the outer diameter was 0.4 mm to 1.5 mm were manufactured by punching a 80Pt-20Ir (wt%) alloy plate manufactured by melting an alloy/rolling.

[0046] Then, a stationary YAG laser beam source arranged to have a beam diameter of 0.4 mm at the focal point was prepared as the laser beam source. The conditions were set such that energy of the output laser beam was 1.8 J/pulse to 3 J/pulse, the width of the pulse was 2 milliseconds to 6 millisecond and the pulse generating frequency was 1 pulse/second to 23 pulse/second. Each noble metal chip was superimposed on the surface of the front surface of the central electrode 3 arranged to be the surface to which the chip was secured. The method shown in Figs. 5A to 5D ($q = 45^\circ$) was employed so that the laser beam source was operated to form the weld portion 10 while the central electrode 3 was being rotated by one rotation at a rotational speed of 60 rpm. After the welding operation was completed, a magnifier was used to measure the maximum width l_{max} and the minimum width l_{min} of the formed weld portion 10. Samples satisfied the relationship that $l_{min}/l_{max} \geq 0.9$ were evaluated as excellent (O), samples satisfied the relationship that $0.9 > l_{min}/l_{max} \geq 0.7$ were evaluated as satisfactory (Δ). Samples satisfied the relationship that $0.7 > l_{min}/l_{max}$ were evaluated as defective (X). Results are shown in Table 2.

[0047] As described above and seen from Table 2, the samples welded under the conditions within the scope of the present invention were evaluated as excellent or satisfactory.

Table 2

| Condition of Pulse | Diameter of Chip (mm) | Thickness of Chip (mm) | PPS | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|-----------------------------|-----------------------|------------------------|------|--|---|----------|---|---|---|---|---|---|---|----|----|----|
| | | | Dmax | | | | | | | | | | | | | |
| 6 μ s 3J/pulse | 1.5 | 0.8 | | | O | Δ | X | X | X | X | X | X | X | X | X | X |
| | 1.5 | 0.8 | | | O | O | O | O | O | O | O | O | O | O | O | O |
| | 1.5 | 0.8 | | | O | O | O | O | O | O | O | O | O | O | O | O |
| 2 μ s 2J/pulse | 0.8 | 0.6 | | | O | O | O | O | O | O | O | O | O | O | O | O |
| | 0.8 | 0.6 | | | O | O | O | O | O | O | O | O | O | O | O | O |
| | 0.8 | 0.6 | | | O | O | O | O | O | O | O | O | O | O | O | O |
| | 0.8 | 0.6 | | | O | O | O | O | O | O | O | O | O | O | O | O |
| | 0.8 | 0.6 | | | O | O | O | O | O | O | O | O | O | O | O | O |
| 2 μ s 1.8J/ pulse | 0.8 | 0.6 | | | O | O | O | O | O | O | O | O | O | O | O | O |
| | 0.4 | 0.6 | | | O | O | O | O | O | O | O | O | O | O | O | O |

| Condition of Pulse | Diameter of Chip (mm) | Thickness of Ship (mm) | PPS | | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|-------------------------|-----------------------|------------------------|------|---|----|----|----------|----------|----------|----------|----------|----------|----------|----|----|
| | | | Dmax | | | | | | | | | | | | |
| 6 μ s 3J/pulse | 1.5 | 0.8 | | X | X | | X | X | X | X | | X | | X | |
| | 1.5 | 0.8 | | O | O | | Δ | Δ | Δ | Δ | | Δ | X | X | X |
| | 1.5 | 0.8 | | O | O | | Δ | Δ | Δ | Δ | | Δ | X | X | X |
| 2 μ s 2J/pulse | 0.8 | 0.6 | | O | O | | O | O | Δ | Δ | Δ | Δ | Δ | X | X |
| | 0.8 | 0.6 | | O | O | | O | O | O | Δ | Δ | Δ | Δ | X | X |
| | 0.8 | 0.6 | | O | O | | O | O | O | Δ | Δ | Δ | Δ | X | X |
| | 0.8 | 0.6 | | O | O | | O | O | O | Δ | Δ | Δ | Δ | X | X |
| | 0.8 | 0.6 | | O | O | | O | O | O | Δ | Δ | Δ | Δ | X | X |
| 2 μ s 1.8J/pulse | 0.4 | 0.6 | | O | O | | O | Δ | Δ | Δ | Δ | Δ | X | X | X |

Claims

1. A method of manufacturing a spark plug comprising a central electrode (3) and a ground electrode (4) disposed such that the side surface of said ground electrode (4) is opposite to the leading end surface of said central electrode (3) and having a structure such that a noble-metal igniting portion (31, 32) having a discharge surface is provided for at least either of said central electrode (3) or said ground electrode (4) at a position corresponding to a spark discharge gap (g) by welding a noble metal chip (31', 32'), said method of manufacturing a spark plug comprising the steps of:

providing a chip securing surface forming portion on the central electrode (3) and/or the ground electrode (4) which is formed with a heat resisting alloy having Ni or Fe as a main component thereof, and superimposing the noble metal chip (31', 32') on a chip securing surface so as to form a superimposed assembly; providing a perimeter laser weld portion (10, 20) across the noble metal chip (31', 32') and the chip securing surface forming portion for the outer surface of the chip constituting the superimposed assembly (70) so that the noble metal chip (31', 32') is secured to the chip securing surface; and forming the perimeter laser weld portion (10, 12) so as to have a maximum outer dimension (dmax), when plan-viewed from the chip interposing direction, which is smaller than 2.0 mm, and formed so as not to reach the discharge surface (31a) in a direction of the thickness of the noble metal chip (31', 32') by using, as a light source for laser welding, a pulse laser beam source having an energy per pulse in the range of from 1.5 J to 6J, a pulse length in the range of from 1 millisecond to 10 millisecond and a pulse generation frequency in the range of from 2 pulse/second to 20 pulse/second.

2. A method of manufacturing a spark plug according to claim 1, wherein a ratio l_{min}/l_{max} of a minimum width l_{min} and a maximum width l_{max} of the perimeter laser weld portion (10, 20), when plan-viewed from the noble metal chip (31', 32') superimposing direction, is 0.7 or higher.

3. A method of manufacturing a spark plug according to claim 1 or 2, wherein the maximum outer dimension dmax of the perimeter laser weld portion (10, 20) is 0.4 mm or greater.

4. A method of manufacturing a spark plug according to any one of claims 1 to 3, wherein the heat resisting alloy for constituting the chip securing surface forming portion has a heat conductivity at 800°C of 30 W/m·K or lower.

5. A method of manufacturing a spark plug according to any one of claims 1 to 4, wherein the noble metal chip (31', 32') is formed into a disc shape, and the outer surface of the chip is irradiated with a pulse laser beam while the superimposed assembly of the noble metal chip (31', 32') and the central electrode (3) or the ground electrode (4) are being rotated, around the central axis of the chip, with respect to the laser beam source (50).

6. A method of manufacturing a spark plug according to claim 5, wherein when the maximum outer dimension of the perimeter laser weld portion (10, 20) is dmax (unit: mm), the relative rotational speed between the superimposed assembly (70) and the laser beam source (50) is 10 rpm or more and the rotational speed of the superimposed assembly (70) is lower than $5\pi (2/dmax)^{1/2}$ (unit: radian/second).

7. A method of manufacturing a spark plug according to any one of claims claim 1 to 6, wherein the superimposed assembly is irradiated with the pulse laser beam (70) in such a manner that an end of the intersection between the surface to which the chip is secured and the outer surface of the chip is included in a laser beam spot, and an irradiation angle of the surface to which the chip is secured with the laser beam is in the range of from 0° to 60°.

8. A method of manufacturing a spark plug according to claim 7, wherein a locating recess (3a, 4a) corresponding to the outer periphery of the chip is formed in the chip securing surface and the noble metal chip (31', 32') is fitted into the locating recess (3a, 4a) so that the superimposed assembly (70) is formed, and an end of the intersection between an end of opened portion of the recess and the outer surface of the chip is irradiated with the pulse laser beam.

9. A method of manufacturing a spark plug according to any one of claims 1 to 8, wherein the main component of the noble metal chip (31', 32') is Pt or Ir.

10. A spark plug comprising:

EP 1 049 222 A1

a central electrode (3) ; a ground electrode (4) disposed such that the side surface of the ground electrode (3) is opposite to the leading end surface of the central electrode (3); and a noble-metal igniting portion (31, 32) having a discharge surface and provided for at least either of the central electrode (3) or the ground electrode (4) at a position corresponding to a spark discharge gap (g);

wherein a chip securing surface forming portion of the central electrode (3) and/or the ground electrode (4) is constituted by a heat resisting alloy having Ni or Fe as a main component thereof;

a perimeter laser weld portion (10, 20) is formed on an outer surface of the noble-metal igniting portion between a noble metal chip (31, 32) superimposed on the chip securing surface forming portion and the chip securing surface forming portion;

a maximum outer dimension d_{max} of the perimeter laser weld portion (10, 20) , when plan-viewed from the chip interposing direction, is smaller than 2.0mm, the perimeter laser weld portion (10, 20) does not reach the discharge surface (31a, 32a) in the thickness direction of the noble metal chip (31, 32), and a ratio l_{min}/l_{max} of the perimeter laser weld portion (10, 20) in the superimposed direction to the chip securing surface is 0.7 or higher.

FIG. 1

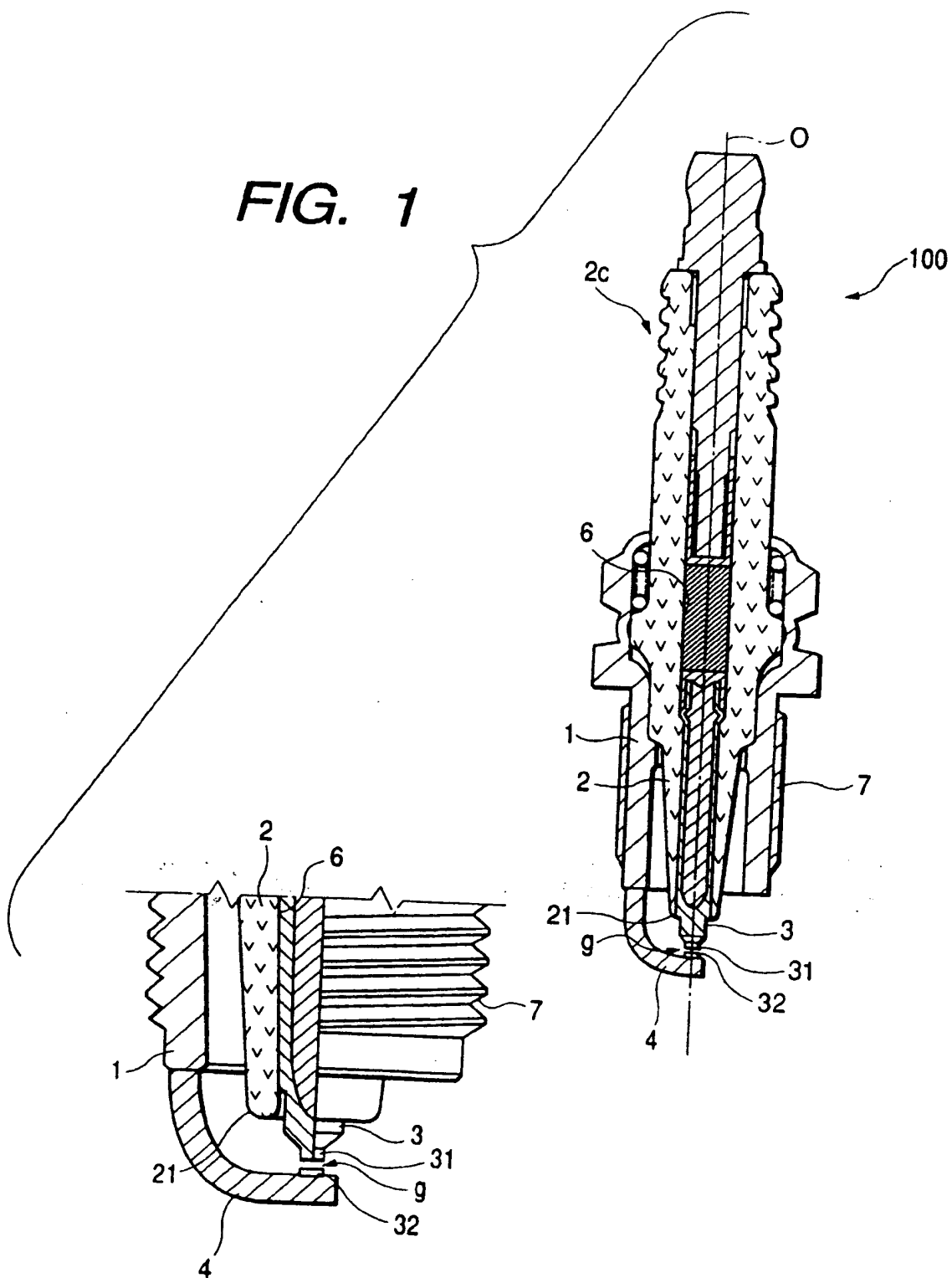


FIG. 2A

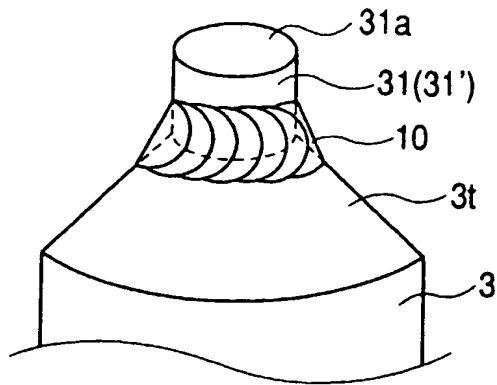


FIG. 2B

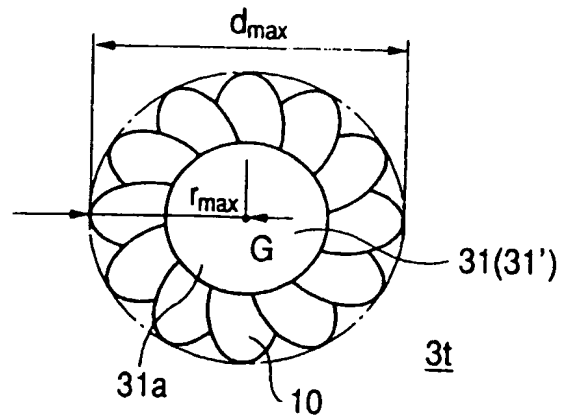


FIG. 3A

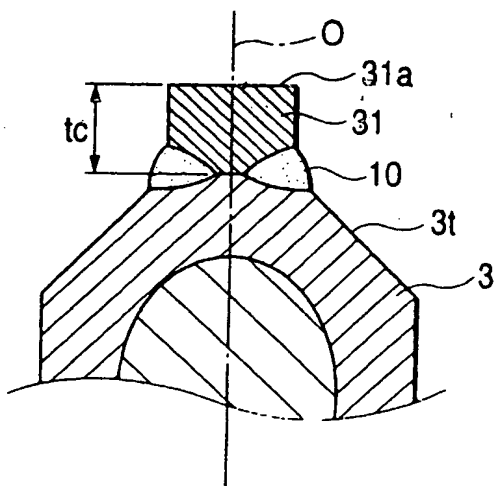


FIG. 3B

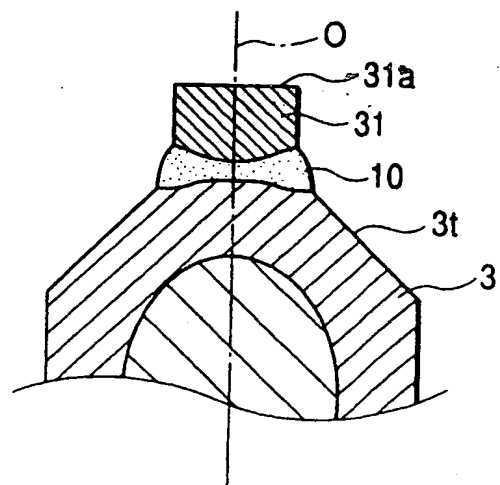


FIG. 4A

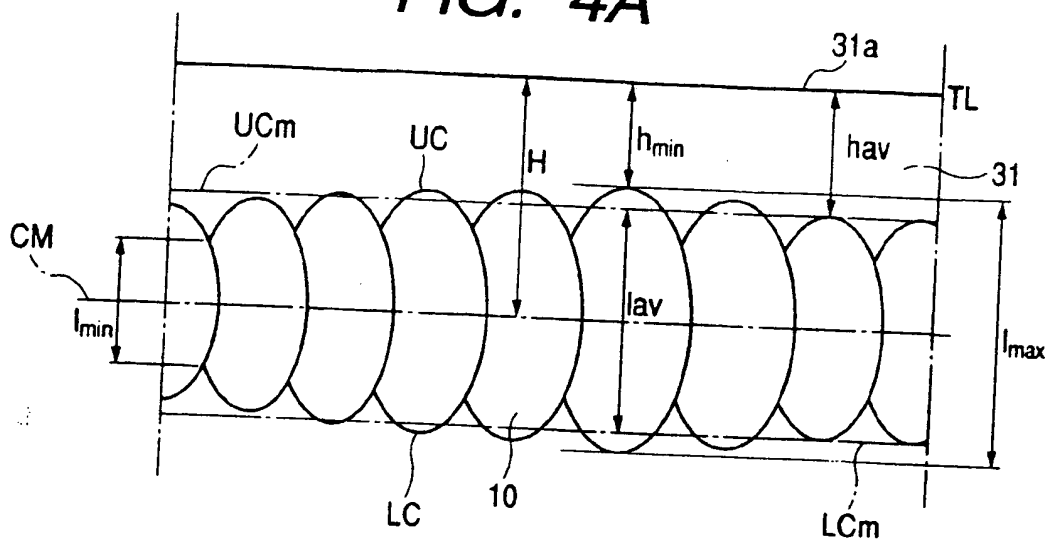


FIG. 4B

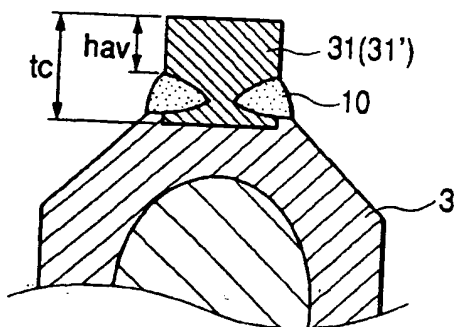


FIG. 4C

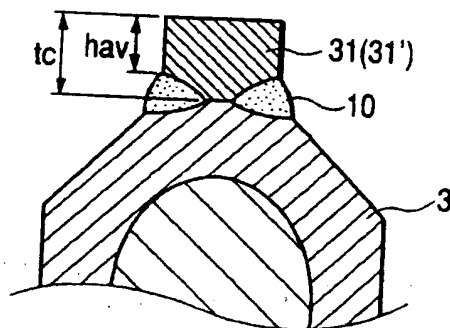


FIG. 4D

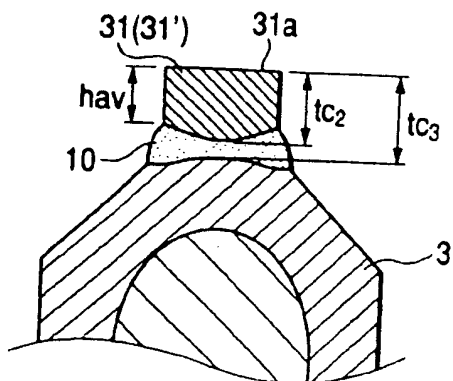


FIG. 5A

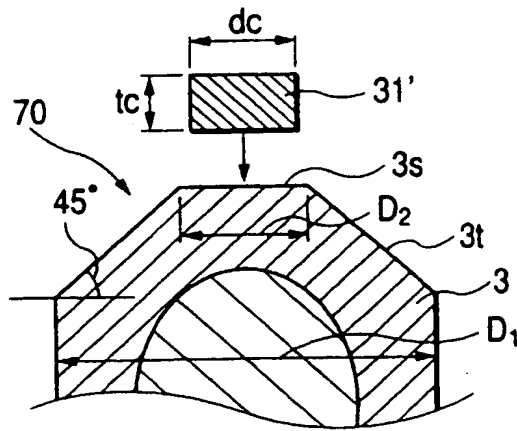


FIG. 5C

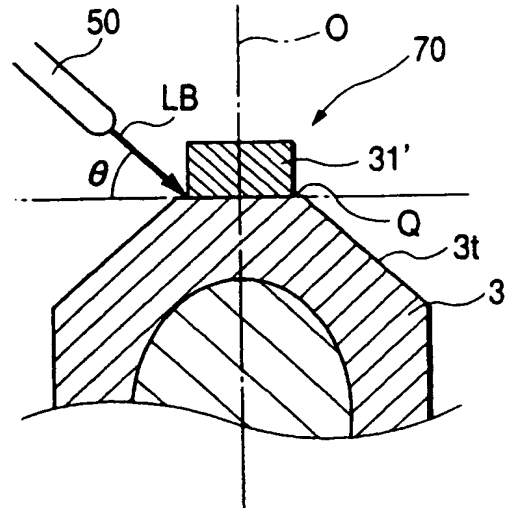


FIG. 5B

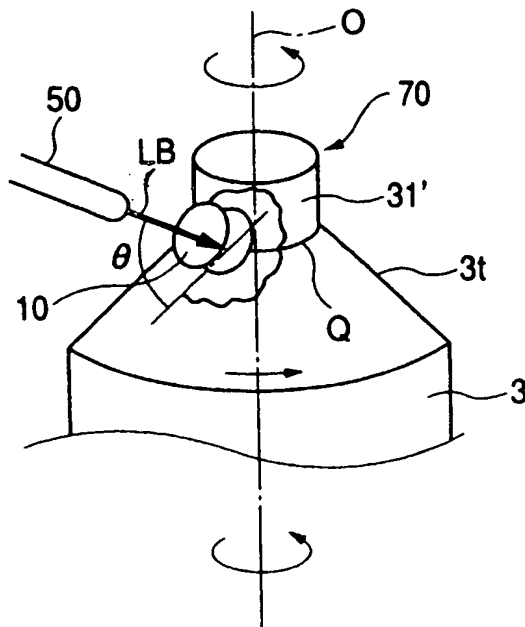


FIG. 5D

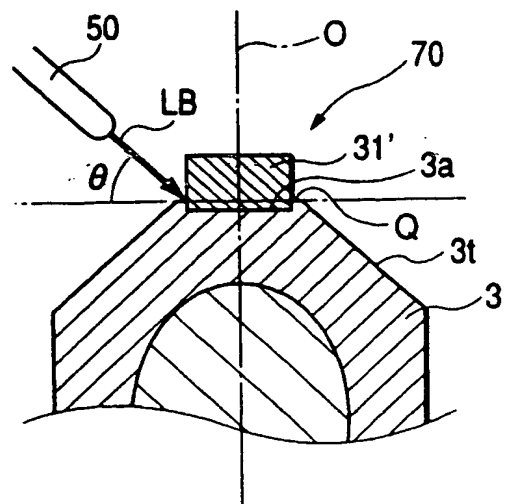


FIG. 6A

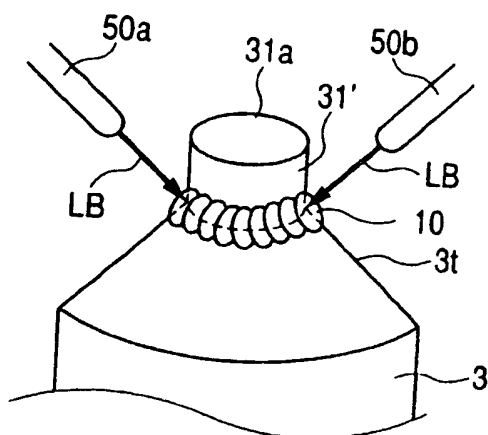


FIG. 6B

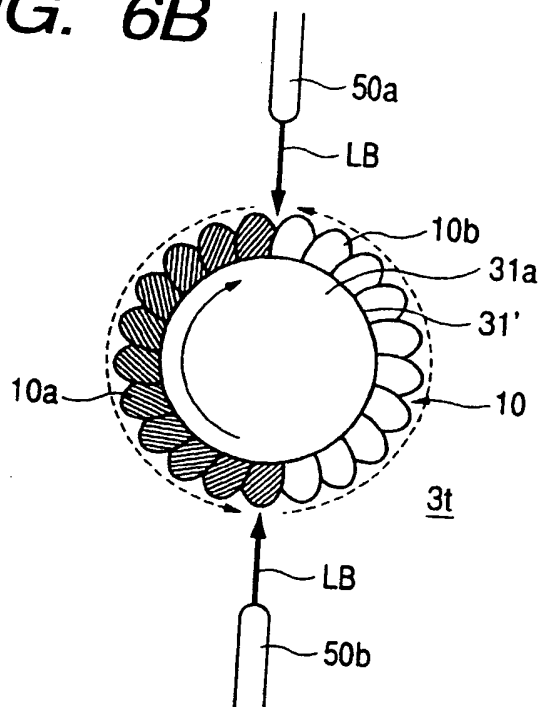


FIG. 7

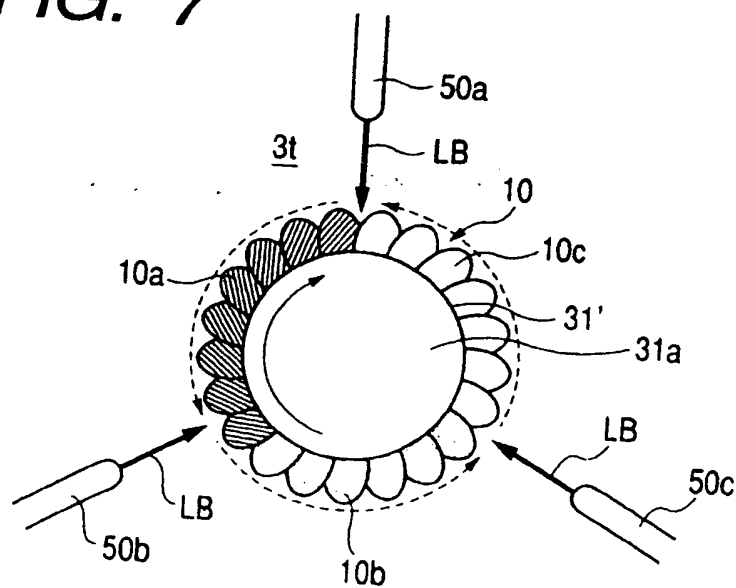


FIG. 8A

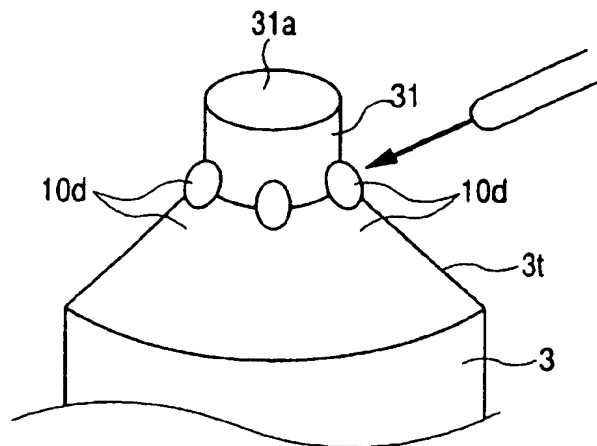


FIG. 8B

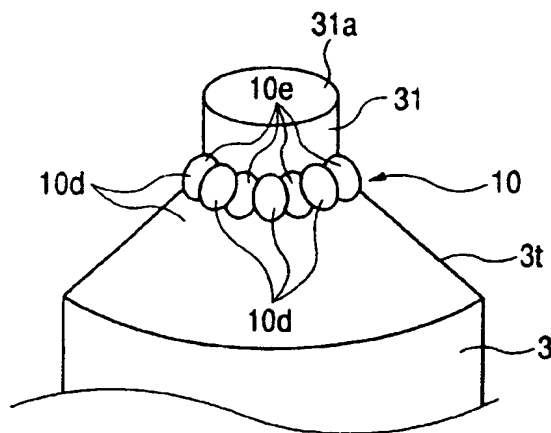


FIG. 9

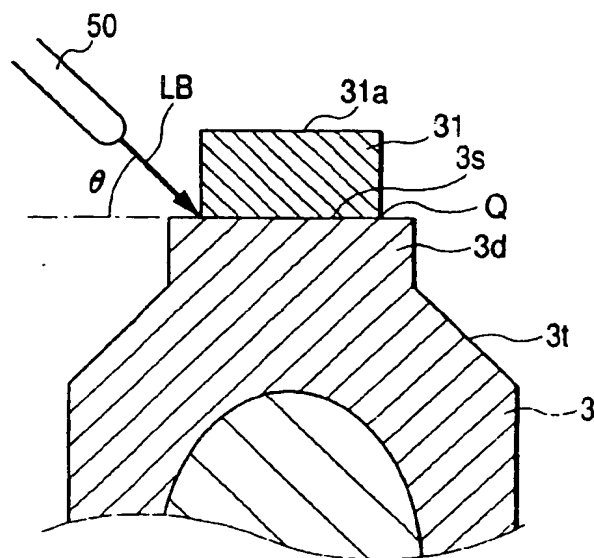


FIG. 10A

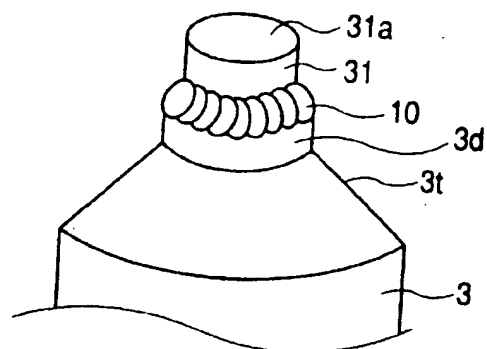


FIG. 10A'

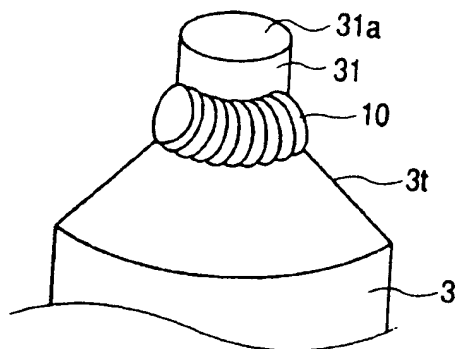


FIG. 10B

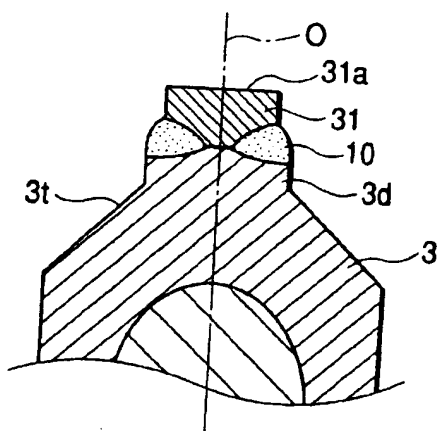


FIG. 10B'

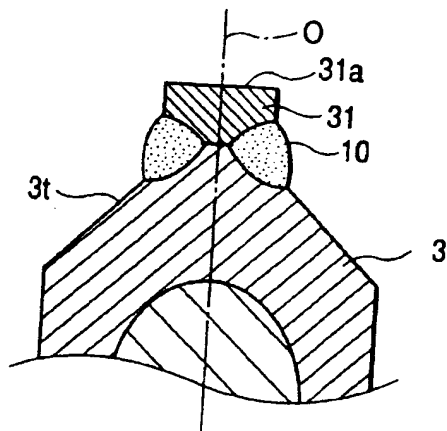


FIG. 10C

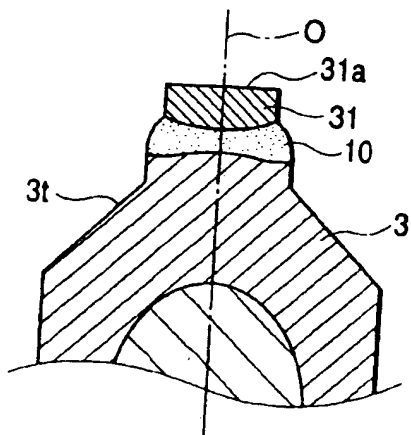


FIG. 10C'

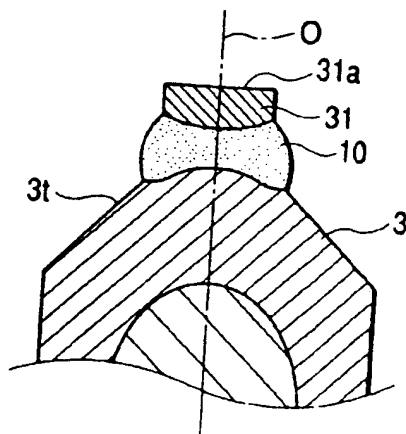


FIG. 11

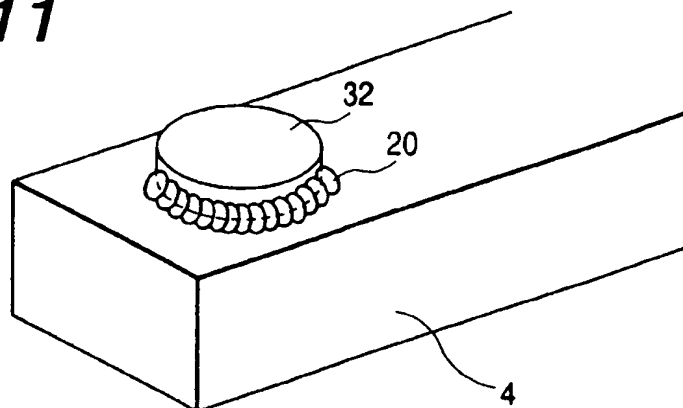


FIG. 12A

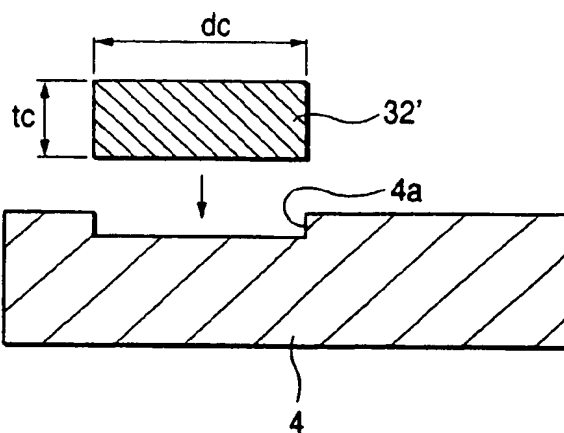


FIG. 12B

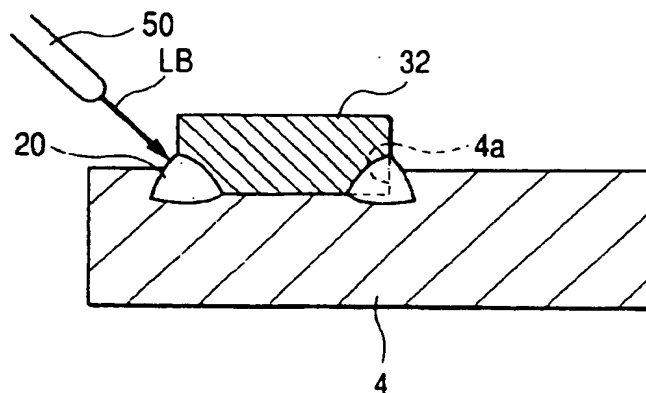


FIG. 13A

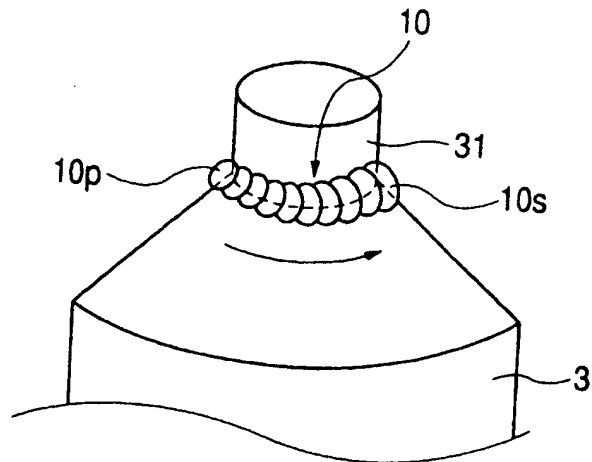
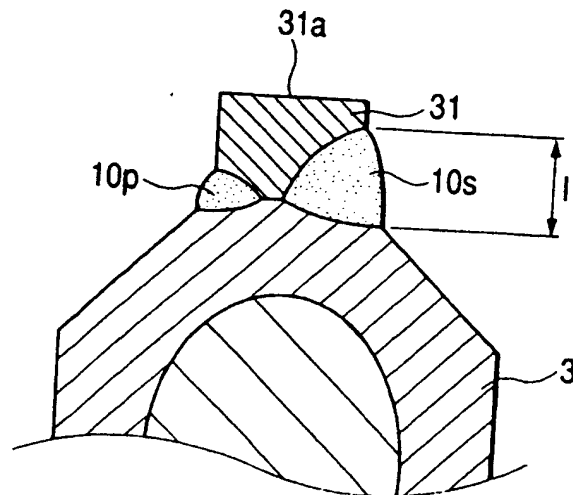


FIG. 13B





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 3605

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|----------------------------------------------|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.7) |
| X | EP 0 575 163 A (NGK SPARK PLUG CO) 22 December 1993 (1993-12-22) | 10 | H01T21/02 |
| A | * column 3, line 36 - column 5, line 16; figures 1-3 * | 1 | |
| A | PATENT ABSTRACTS OF JAPAN vol. 1996, no. 03, 29 March 1996 (1996-03-29) & JP 07 296943 A (NGK SPARK PLUG CO LTD), 10 November 1995 (1995-11-10) * abstract * | | |
| D,A | EP 0 583 103 A (NGK SPARK PLUG CO) 16 February 1994 (1994-02-16) | | |
| D,A | PATENT ABSTRACTS OF JAPAN vol. 018, no. 263 (E-1550), 19 May 1994 (1994-05-19) & JP 06 045050 A (NGK SPARK PLUG CO LTD), 18 February 1994 (1994-02-18) * abstract * | | |
| D,A | PATENT ABSTRACTS OF JAPAN vol. 1998, no. 09, 31 July 1998 (1998-07-31) & JP 10 112374 A (DENSO CORP), 28 April 1998 (1998-04-28) * abstract * | | TECHNICAL FIELDS SEARCHED (Int.Cl.7) |
| | | | H01T |
| The present search report has been drawn up for all claims | | | |
| Place of search THE HAGUE | | Date of completion of the search 8 August 2000 | Examiner Bijn, E |
| CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document | | | |

EPO FORM 1503 03.82 (P04.001)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 00 30 3605

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

08-08-2000

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
| EP 0575163 A | 22-12-1993 | JP 2853108 B | 03-02-1999 |
| | | JP 6036856 A | 10-02-1994 |
| | | DE 69304812 D | 24-10-1996 |
| | | DE 69304812 T | 30-01-1997 |
| | | US 5440198 A | 08-08-1995 |
| JP 07296943 A | 10-11-1995 | NONE | |
| EP 0583103 A | 16-02-1994 | JP 2853109 B | 03-02-1999 |
| | | JP 6045050 A | 18-02-1994 |
| | | JP 2853110 B | 03-02-1999 |
| | | JP 6068956 A | 11-03-1994 |
| | | DE 69306499 D | 23-01-1997 |
| | | DE 69306499 T | 03-04-1997 |
| JP 06045050 A | 18-02-1994 | US 5320569 A | 14-06-1994 |
| | | JP 2853109 B | 03-02-1999 |
| | | DE 69306499 D | 23-01-1997 |
| | | DE 69306499 T | 03-04-1997 |
| | | EP 0583103 A | 16-02-1994 |
| JP 10112374 A | 28-04-1998 | US 5320569 A | 14-06-1994 |
| | | EP 0834973 A | 08-04-1998 |
| | | US 5982080 A | 09-11-1999 |

EPO FORM P0159

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

